FIRE-PROOFING WOOD WITH CHEMICALS

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FIRE PROOFING WOOD WITH CHEMICALS*

By
G. M. HUNT
In Charge, Section of Wood Preservation
and
T. R. TRUAX
Senior Wood Technologist

The need for increasing the resistance to fire of lumber and structural timber is obvious. While it is true that the fire hazard of wooden structures of widely different types can be reduced by proper methods of design and construction to the point where they are reasonably safe, it is also true that effective and economical treatments of wood to reduce its inflammability would increase the fire safety of wood structures and permit the use of wood in places where its combustibility now excludes it.

The problem has been recognized for centuries and hundreds of different fire-retarding coatings and impregnating soulutions have been proposed within the last 200 years. The majority of the proposals have been based upon inadequate knowledge, and are ineffective, too expensive, or for some other reason impractical. Some of the impregnation methods, however, have sufficient effectiveness and practicability to have found commercial use. It is possible now to buy commercially fire-proofed wood so resistant that it will not of itself support combustion. Effectively treated wood can be destroyed only by continuous exposure to heat from an outside source; when the heating is discontinued the burning ceases. In contrast with untreated wood the difference is of the greatest practical significance.

Fire-Proofed Wood Defined

The term "fire-proof" as applied to structural materials is technically incorrect. Even stone, concrete, and metals are destroyed when exposed continuously to sufficiently high temperatures. Wood treated by the most effective methods known is destroyed in time by chemical decomposition if the surrounding temperatures are kept sufficiently high. Popular usage, however, employs the terms "fire-proof", "fire-proofed", and "fire-proofing" in connection with wood in the sense that the treated wood will not support flame or contribute to its own destruction. Convenient words that are technically correct are lacking, especially as substitutes for "fire-proofed" and "fire-proofing." The popular terms will, therefore, be used in this article with the meaning defined above.

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Commercial Impregnation Treatments

Although good quality, commercially fire-proofed wood, treated by impregnation processes is available, it is not extensively employed. Its use in North America is limited for the most part to wooden floors, doors, and trim in large office buildings of fire-proof construction in the city of New York.[1] Its limited use is due not to lack of fire resistance, but to its relatively high cost. A contributing limitation is the fact that fire-proofing processes are not standardized and generally known. The various fire-proofing companies presumably use different formulas although it is not possible to be certain of this for the formulas are kept secret. There is also considerable secrecy as to their methods of impregnating the wood and of drying it afterwards. A further limiting factor is the lack of accepted standard methods of measuring the effectiveness of the treatment. The obvious advantages that would accrue from the widespread use of adequately fire-proofed wood justify considerable effort to overcome these obstacles.

Research in Fire-Proofing

Research has not been entirely lacking in the field of fire-proofing wood, as a review of the literature on the subject will show.[2,3,4] The various investigations reported have contributed much to the general knowledge of the subject and have laid foundations for further progress, but none have resulted in a sufficiently convenient satisfactory and inexpensive method of fire-proofing wood, nor have any produced testing and control methods that are generally accepted and satisfy the needs of prospective purchasers of fire-proofed wood. Unless the benefits of a more extensive use of fire-proofed wood are to be abandoned much additional research must be done.

The U. S. Forest Products Laboratory at Madison, Wis., early recognized the importance of fire-proofing studies and undertook some work in this field. The results of its findings in these earlier studies were published in 1915.[2] The continual demand for information on the subject

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[1] Garratt, G. A. Amer. Lbrman., No.2713, pp.56-7; No.2714, pp.52-3, 1927.

[2] Ingberg, S. H. Safety Eng., V.53, No.1, pp.29-35, 1927.

[3] Truax, T. R. and Harrison, C. A. Trans. Amer. Soc. Mech. Engrs. Wood Ind., V.52, No.17, pp.33-40, 1930.

[4] Woolson, I. H. Rep. Proc. Inter. Fire Prev. Congr., p.257, 1904.

[5] Prince, R. E. Proceedings of the Natl. Fire Protect. Assn., pp.108-58, 1915.

and th obvious need for improvement in fire-proofing and fire-testing teehnie caused the Laboratory to take up the investigation again in 1927. The Forest Products Laboratory entertains no delusion that its studies will sweep away the obstaelcs to the extensive usc of fire-proofed wood, but hopes that its eontributions, added to thosc of other investigators, will bring the desired objective definitely nearer. Sevcral reports[3,6,7] of the progress made in the recent investigations have thus far been published. The work will undoubtedly continue for several ycars.

Fire-Retardant Chemieals

Although fire-proofing eompanies do not make publie their formulas, there is reason to belicve that thc monobasie and dibasie phosphates of ammonia arc quite generally uscd in impregnation processes throughout the world and that onc or the other eonstitutes an important part of most good eommereial formulas used in fire-proofing by impregnation. Other chemicals are added for different purposes aeeording to the ideas of the respective eompanies or inventors and there may be some good formulas in use that eontain no ammonium phosphates.

The chief advantage of the ammonium phosphates is their high effeetiveness in retarding the combustion of wood, coupled with the fact that they do not give the wood undesirable properties to a sufficient degree to make the use of the treated wood impraetieable. There are many ehemicals that have sufficient fire-retarding ability to be used,[6] if it were not for their undesirable properties. Calcium ehloride, for example, attracts moisture and under eonditions of high humidity would tend to keep the wood too damp if used in sufficient quantities to get good fire resistanee. Some ehemieals attaek the wood and reduce its strength, some destroy or interfere with paint and varnish adhesion, some discolor the wood or make it too hard to work with edged tools, some interfere with gluing, or are poisonous or too expensive, and practically all that are in eommercial use are too easily leached from thewood to remain permanently effeetive when used out of doors. Altogether, the requirements are so rigid that no single chemieal thus far meets them. Mixtures of ehemieals offer greater promise of meeting these requirements than single ehemicals and it is quite possible that, in due eourse, highly effective, nonleaching, and otherwise acceptable treatments will be possible at moderate cost.

In many places where fire-resistant wood is desired, resistance to deeay and insects is also important. In developing fire-proofing formulas this should be taken into consideration. It should not be difficult to include in the mixture some toxic ehemical which by adding

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[6] Truax, Hunt, Harrison, Baeehler. Proc. Amer. Wood-Pres. Assn., V26, pp. 130-64, 1930; V.27, pp.104-41, 1931; V.28, pp.71-93, 1932. V.29, 1933.

[7] Truax, T. R. The fire-proofing of wood, Proe. Natl. Fire Protect. Assn., pp. 187-204, 1931.

resistance to decay and insects would materially increase the value of the treated wood and thus help justify the cost of treatment.

One of the chief disadvantages of the more desirable of the present fire-retarding chemicals is their cost. The quantity required per cubic foot of wood is so large that the cost of the chemical has probably been the largest single item of cost in the production of commercially fire-proofed wood. For a high degree of effectiveness approximately four pounds of the more effective chemicals are required per cubic foot of wood, or perhaps 300 pounds per thousand feet board measure. The cost of the chemical alone may, therefore, increase the cost of the lumber from $15 to $25 per thousand feet. When the necessary treating, drying, and handling costs, plant depreciation, and profit are added, the selling price of thoroughly fire-proofed wood may, even under present conditions, easily exceed that of similar untreated wood by $40 to $50 per thousand feet board measure. The cost of the treated wood then becomes so high that it sharply limits the extent to which fire-proofed wood is used.

Application of Fire-Proofing Chemicals

Methods of applying fire-proofing chemicals to wood vary from simple surface applications and coatings to thorough impregnation. Obviously there can be a wide range in the costs of such treatments, the degree of effectiveness obtained, the ease of application, and the equipment required. At the one extreme is wood that ignites and burns almost as easily as though untreated and at the other extreme wood that ignites at higher temperatures and burns only when a considerable quantity of heat is supplied from an outside source. There are intermediate treatments which reduce the hazard of untreated wood and which may ultimately find a large field of usefulness. The choice of a method of protecting wood against fire must be based upon the requirements of the use and such practical considerations as cost and convenience.

Surface applications vary considerably in effectiveness, but are not dependable where severe fire exposure continues for some time. A thick coating of suitable composition may delay ignition and spread of flames for a long time when the fire source is small, but when exposed to a large fire their retarding effect is only temporary. On the other hand, coatings can be applied to wood in place, or to fabricated products, by brush, spray, or dipping methods with very little equipment. They are relatively cheap and their use requires no technical training or experience. Coatings offer the opportunity of reducing the hazard of wood by decreasing the number of fires starting from small sources and by decreasing the rate of spread in the early stages of a fire.

The methods and apparatus used for injecting fire-proofing chemicals into wood are practically the same as for injecting preservatives. The wood is sealed within a treating cylinder and the treating solution forced in by means of pressure. If the treated wood is to be used for purposes that require no cutting after treatment, a moderate degree of

penetration may be sufficient even though a core of wood in the center of each piece may remain unimpregnated. When the lumber must be cut up into smaller pieces after treatment, or must be moulded or shaped in such a way that a considerable depth of wood is removed from the surface, complete penetration is a necessity. The effectiveness of the chemical would be largely dissipated if the subsequent cutting exposed any considerable areas of untreated wood.

The deep-penetration requirement complicates considerably the problem of the commercial fire-proofer, for wood is generally much more resistant to deep impregnation than is commonly supposed. The sapwood of most commercial woods is not difficult to treat and when all-sapwood lumber is available it offers no serious treating problem. Most lumber, however, contains some boards that are all heartwood and many boards of mixed sapwood and heartwood. Such material, especially in species with highly resistant heartwood like white oak or red gum, thoroughly tests the skill of the most experienced treating engineer. Complete impregnation of the heartwood in lumber over one inch in thickness requires great care and watchfulness as well as skill. The temperatures and pressures used may easily be made so severe that the lumber is ruined during the treating process. These strict limitations naturally affect the treating costs.

Evaluating Fire-proof Treatments

Two of the difficulties in the way of more extensive use of fire-proofing treatments for wood are the lack of standard methods of test and the difficulty of interpreting the results of tests in terms of performance standards. Until adequate progress is made along these lines there will be misunderstanding, misrepresentation, and slow appreciation of the value of fire-proofing processes.

Tests on the inflammability or fire resistance of wood may be grouped into two classes: Tests on small pieces or representative samples, and tests on built-up assemblies under standard time-temperature conditions. Tests on built-up assemblies are intended to measure the performance of materials under approximate fire conditions, while tests on small samples are useful as measures of one or more of the properties of fire-proofed wood and, in treating-plant control, as measures of the thoroughness of treatments. Built-up assembly tests are expensive and are not adapted to systematic checking of commercial treatments nor to extensive routine laboratory or development work.

Although a large number of tests have been used or proposed for small pieces or samples and most of them show differences in fire resistance between untreated and fire-proofed wood, the results of many are of doubtful value because of uncontrolled conditions and factors in the test. Furthermore, there has frequently been failure to use sufficiently significant units of measurement and little or no correlation of the

conditions of the test to fire conditions. The fire-tube test developed by the U. S. Forest Products Laboratory,[g] has been found valuable in studying the fire-retarding effectiveness of various chemicals. The test has considerable merit from an inspection and control standpoint and is receiving consideration as a standard method by interested agencies. The extent to which it will prove to be an indicator of performance in assembly tests remains to be determined.

Problems of the Industry

The major problems facing the fire-proofing industry are the improvement of methods of treatment; the lowering of costs; the standardization of materials, processes, and test methods; and the elimination of secrecy. If these things can be accomplished, the industry can grow considerably. If they cannot be accomplished, expansion is not likely to be great or rapid.

The research worker in wood fire-proofing, whether within the industry or in independent laboratories, faces several specific problems whose solution will supply the foundation for the expansion of the industry. Among these are: (a) developing new test methods or improving old ones; none of the methods yet devised has been accepted as a standard measure of fire resistance although several of them give very useful and indicative information; (b) finding chemicals, or mixtures of chemicals, that are free from other objections and are very cheap or are so effective that they can be used successfully in much smaller quantities than those now available; (c) finding chemicals or mixtures of chemicals that are not only effective against fire and moderate in cost, but also effective against decay and insect attack, and that do not leach rapidly in outdoor uses.

Questions of more purely scientific interest that appear of less immediate practicability, but may in the long run contribute greatly to solving the fire-proofing problems are: Just how does wood burn? That is: What chemical and physical reactions are involved? How do fire-proofing chemicals retard combustion? and, Why are some chemicals so much more effective than others? All of these questions are exceedingly interesting to investigate, but years may be consumed in finding their answers.

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[g] Truax, T. R. and Harrison, C. A. Proc. Amer. Soc. Testing Materials, V.29, Pt. 2, pp.971-88, 1929.